DOCUMENT RESUME

ED 434 804 SE 061 381

TITLE	A Science Odyssey: A Social Studies and Science Resource for Middle- and High-School Educators. Educator's Guide.
INSTITUTION	WGBH-TV, Boston, MA.
SPONS AGENCY	National Science Foundation, Arlington, VA.; IBM Foundation.; Arthur Vining Davis Foundations, Miami, FL.; Carnegie Corp. of New York, NY.; Corporation for Public Broadcasting, Washington, DC.
PUB DATE	1997-00-00
NOTE	38p.; The five "Science Odyssey" TV programs premiered across January 11-15, 1998. A companion book of the same name, by Charles Flowers, was projected for publication the same month. Additional funding provided by Becton Dickinson and Company.
AVAILABLE FROM	WGBH Boston, 125 Western Ave., Boston, MA 02134 ("Educator's Guide" and related video products).
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	High Schools; *Integrated Activities; Life Style; Middle Schools; Quality of Life; Resource Materials; *Science And Society; *Science History; Scientific Enterprise; *Scientific Research; Social Change; Social Problems; *Social Studies; Teaching Guides; Technology; Technology Education; Values

ABSTRACT

This interdisciplinary guide provides activities, discussion questions, and information to help teachers use the series of five special PBS programs entitled "A Science Odyssey" in the classroom. For each Science Odyssey program, the guide features: (1) an overview of the program; (2) a summary of program contents and story segments; (3) a thematic feature designed to spark student thoughts and interest; (4) several suggested activities and an in-depth investigation related to the program topic. Program titles include: (1) "Matters of Life and Death," which addresses how remarkable breakthroughs in surgery, drugs, and medical technology raise ethical questions and change our assumptions about life and death; (2) "Mysteries of the Universe," which details how twin revolutions in physics and astronomy have transformed our perceptions of the universe; (3) "In Search of Ourselves," which covers our scientific attempts to solve the puzzle of human behavior; (4) "Better, Bigger, Faster," which addresses the ways in which new technologies such as the automobile, synthetic materials, and computers have changed our lifestyles; and (5) "Origins," which addresses the scientific discoveries that have helped explain the origins of our planet and our species. (WRM)

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ED 434 804

Educator's Guide

A SCIENCE ODYSSEY

A social studies and science resource for middle- and high-school educators

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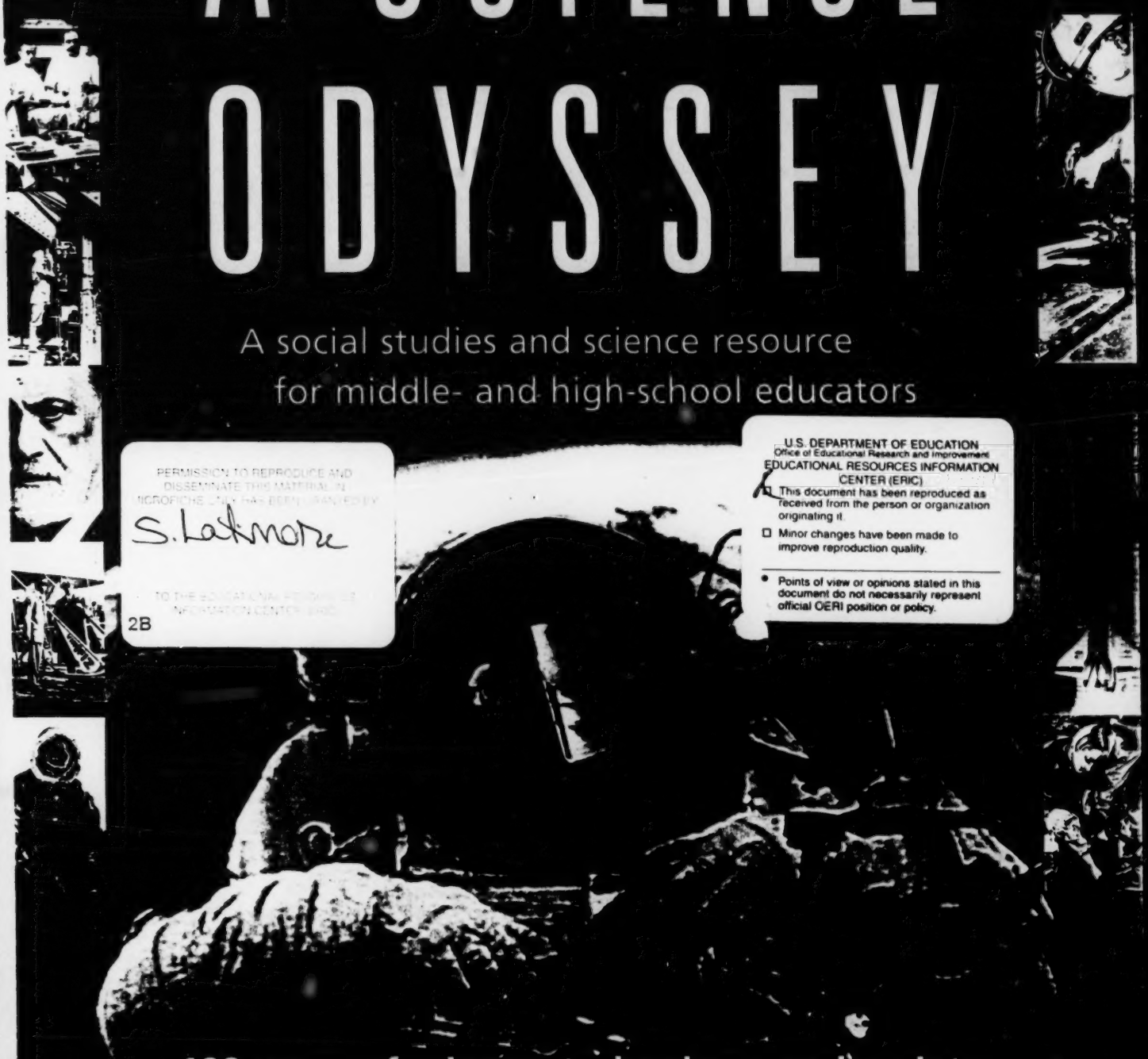

100 years of science, technology, and society

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NATIONAL SCIENCE FOUNDATION
4201 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22230

Dear Educator:

The National Science Foundation (NSF) is pleased to be a part of *A Science Odyssey*. NSF's support for science research and education is an investment in our future, and *A Science Odyssey* will inspire each of us to become active participants in shaping that future. Individuals, society, culture, and politics have all shaped twentieth-century science and will continue to influence the questions we ask and the answers we get throughout the twenty-first century. *A Science Odyssey* will help us explore the nature of science and understand it as a profoundly human endeavor.

By using the resources and activities in this teacher's guide together with segments from the broadcast series and any of the other multimedia components that make up this far-reaching project, you join thousands of others across the country in an exciting and educational science odyssey.

Sincerely,

Hyman Field

Hyman Field
Acting Deputy Division Director
Elementary, Secondary, and Informal Education
National Science Foundation

Office of the Vice President, Corporate Community Relations

IBM

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Armonk, New York 10504-1783
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(914) 765-7684 (Fax)

Dear Teachers:

At IBM, we know that providing students with the skills they need to succeed in work and in life is one of the toughest jobs. In an increasingly demanding and complex global economy, we also think that it is job number one. This is why we appreciate and applaud your dedication and hard work to help our children learn.

In our ongoing commitment to education reform and high academic standards, IBM is delighted to bring PBS' "A Science Odyssey" to you and your students. We believe that this wonderful, informative program will ignite children's natural curiosity, feed their desire to learn and grow, and stretch their minds and imaginations. We hope that these accompanying curricular materials will help you build on their interest, challenge them, and support their efforts to achieve at the highest levels.

"A Science Odyssey" describes the incredible journey in knowledge and discovery that we have made in this century. IBM looks forward to working with you to find new ways to prepare our students to continue this journey into the 21st century.

Sincerely,

Stanley S. Litow

Stanley S. Litow

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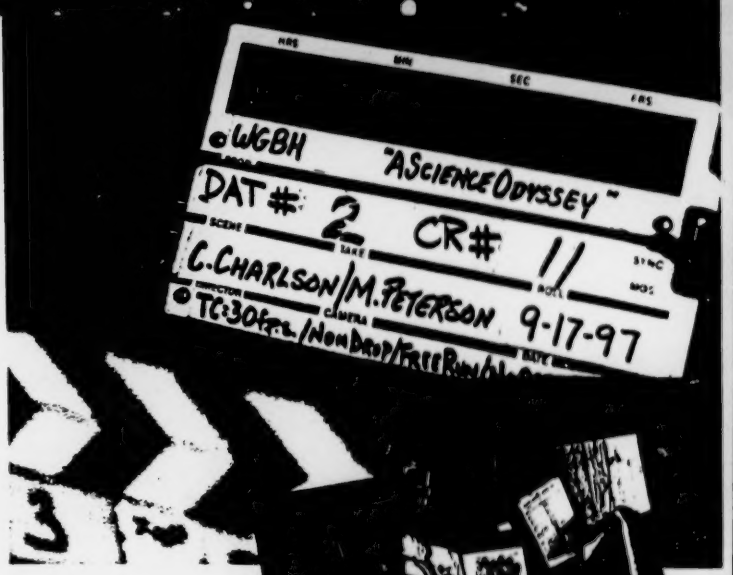
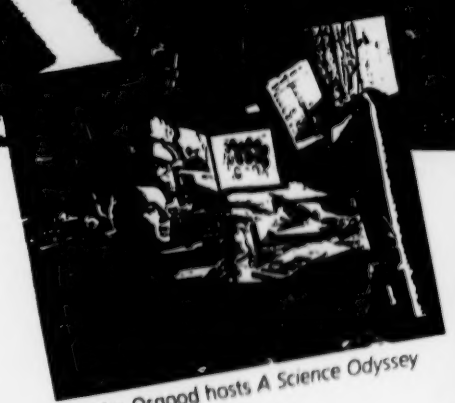
What have we learned in the past 100 years about life and the forces of nature? What have we learned about the universe and our own origins? How have we learned it? And how has this knowledge changed us, for better or worse? Questions such as these sparked the creation of *A Science Odyssey.*





Charles Osgood hosts *A Science Odyssey*

Using original film, archival footage, photos, animations of scientific phenomena, primary source documents, expert interviews, and oral history, *A Science Odyssey* tells tales of achievement and failure, greatest moments and worst nightmares. Each two-hour episode follows a different scientific area through the twentieth century: medicine and public health, physics and astronomy, human behavior, technology, and earth and life sciences. Several stories make up each program, capturing the character of scientific discovery while maintaining a human perspective.

A note from the producer

Welcome to *A Science Odyssey!* We've designed this series to offer young people an opportunity to consider an entire century of scientific and technological achievements, to recast their perceptions of science and scientists, and to be intrigued, even inspired, by the personal stories behind the science headlines and controversies.

The *Science Odyssey* team has experienced its own process of discovery while developing the project. If we can pass on a fraction of the fascination we feel about the material, we'll consider ourselves successful.

May you and your students find *A Science Odyssey* to be a truly rewarding journey through the twentieth century—one that will end with a new and richer view of science.

Thomas Friedman
Executive Producer

The stories provide natural stopping points, as well, making *A Science Odyssey* especially suitable for classroom use. And, because all programs include aspects of history, science, social studies, and technology, teachers of any one discipline will find useful material in more than one episode. For example, a history instructor teaching World War I might show students the segment from "Bigger, Better, Faster" about the use of airplanes in the war, and the segment from "In Search of Ourselves" on shell shock that resulted from battle. A chemistry teacher working on atoms and isotopes might use the segment on atomic structure from "Mysteries of the Universe" and the one on radioactivity from "Origins."

You may tape and use the programs in class for three years after broadcast—or purchase an indexed set of videotapes (see page 5).

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Excite your students about social studies and science. This interdisciplinary guide provides activities, discussion questions, and information to help you use *A Science Odyssey* in your classroom. Each *Science Odyssey* program is covered in four pages as shown below. Scan the Program Contents for topics appropriate to your teaching, percolate student interest with a creative activity idea, or delve right in to an in-depth investigation on the topic.

Using this guide

Introduction provides an overview of the program.

Program Contents summarizes the program and lists the story segments in the order in which they appear. Animation sequences that dramatize scientific principles are highlighted.

A thematic feature highlights an item of interest related to the topic. It can be used to spur students' thoughts and discussion.

Activities offer several ideas for using the programs.

In-depth Investigation is a more lab-like activity, divided into steps.

Overview summarizes what students do during the activity.

Learning Goal suggests what students should understand or be able to do as a result of the activity.

Video Link identifies program segment relevant to the activity.

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Expectations and outcomes for In-depth Investigations and selected Activities are on page 30.

More has been learned in the last century than in any other—every scientific discipline has been shaken to its core by new discoveries. *A Science Odyssey* hopes to clear away notions of science and scientists as hopelessly esoteric, and to rekindle curiosity and spark the imagination by showing the human and social nature of science. *A Science Odyssey* portrays science not as a static body of knowledge, but rather as an important way of solving problems and looking at the world.

A Science Odyssey is the most comprehensive science education initiative in PBS history. The broadcast series and this guide are only two of the many ways you can participate in the project. Here are some more...

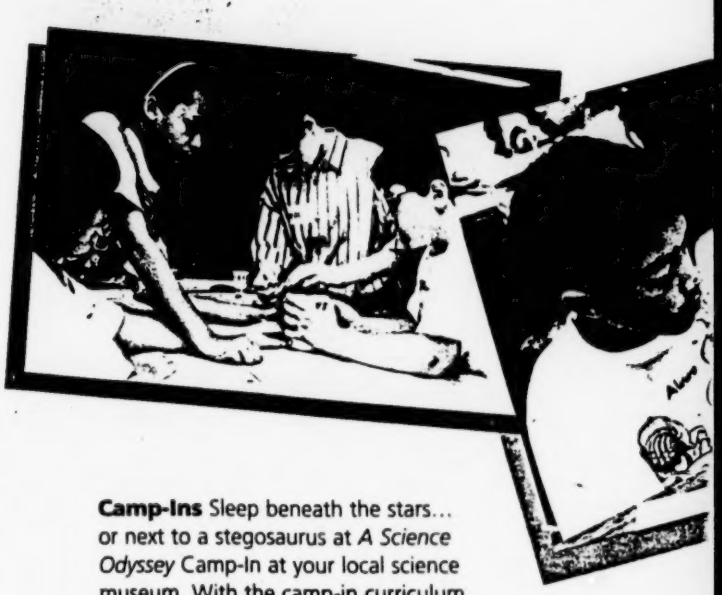
Project overview

Museum-Based Activities

Find out if a science center in your area is hosting any of these *Science Odyssey* activities.

Science Theater *Matters of the Heart* is a fascinating drama about the effects of changing medical technology on one twentieth-century family. This moving 20-minute play by Jon Lipsky spans the century, the continent, and several lives, examining developments that have made heart transplants a reality and a second chance for over 3,000 people a year.

Public Demonstration Are we alone? Or will our continual explorations of space finally reveal those "little green men"? *Life Beyond Earth* looks at the technological and scientific advances over the past century that have made looking for life "out there" a seemingly common dinner-table topic. In the course of the demonstration, students will learn about radio waves, rocketry, computer enhancement, and scanning electron microscopy.



Camp-Ins Sleep beneath the stars... or next to a stegosaurus at *A Science Odyssey* Camp-In at your local science museum. With the camp-in curriculum *Sending Messages*, students ages 9–14 spend an evening exploring how telephones, computers, and even our bodies transmit information using codes and signals. Not only that—campers get to sleep overnight at the museum!

Note These activities will be available to science centers nationwide. Programming at individual institutions will vary. Check the Web site for listings of participating museums, or write to Thea Sahr at WGBH, Educational Print and Outreach, 125 Western Ave., Boston, MA 02134.

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Video Products

Series Videocasettes Videocassettes of *A Science Odyssey* are available for purchase from PBS Video after the broadcast. Call (800) 344-3337 to order. Each set comes with printed program indices; you can look up a particular subject or scientist and fast-forward to just the right spot on the video.

Educational Videos WGBH is producing six short videotapes based on *A Science Odyssey*. Gripping stories and provocative questions are ideal for community groups and schools serving 11–14-year-olds. These videos come with a 24-page activity guide to help youth workers and educators guide young people as they explore the core themes of *A Science Odyssey*. Available after the series premieres from PBS Video. Call (800) 344-3337 to order.

Science-By-Mail®

Help students participate in scientific inquiry by using hands-on activity packets created in conjunction with *A Science Odyssey*. The national Science-By-Mail program pairs students in grades 4–9 with scientist pen-pals who offer advice and encouragement. Participants receive two activity kits during the school year to explore and share results with their scientists. The first kit, Picture This!, invites students to explore the range of imaging technologies developed throughout the twentieth century and the second, Get the Signal!, challenges them to investigate the many ways humans communicate with each other. Students may participate individually or as a class.

For more information, a free brochure, or to sign up, call Science-By-Mail at (800) 729-3300 or (617) 589-0437, or e-mail SBM@A1.mos.org.

The Book

Read all about it! *A Science Odyssey* by Charles Flowers is an accessible and visually appealing companion book that reflects the themes and material of the project. Published by William Morrow & Company, *A Science Odyssey* will be available in January 1998 in bookstores and libraries from coast to coast.

The Web Site

Twentieth-century science at your fingertips! The *Science Odyssey* Web Site offers activities and biographies, detailed information on science concepts and more to help you and your students experience the ups and downs of 100 years of science, technology, and discovery. Museums, libraries, and other organizations hosting *Science Odyssey* events will be posted. Plus, all print materials such as this guide or the script for *Matters of the Heart* will be downloadable from the site.

http://www.pbs.org/aso
Beginning in December 1997

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American life expectancy has increased by more than 30 years in the past century. The limitations of medical practice dissolve with the passing years, as new knowledge and equipment enable doctors to do what was once impossible. As scientists and physicians continue to push the expanded boundaries of medical science, society must weigh the miraculous possibilities against psychological and social burdens, and make choices that once were left to fate. How far are we willing to go to prolong life? Who will benefit from new medical practices—and at what cost?

Matters of Life & Death

Program 1

Premieres January 11, 1998

Scientific and technological answers to a problem sometimes cause other problems.

Operation Cat Drop

In the early 1950s, the Dayak people in Borneo suffered from malaria. The World Health Organization had a solution. They sprayed large amounts of DDT to kill the mosquitoes which carried the malaria. The mosquitoes died, the malaria declined; so far, so good. But there were side-effects. Among the first was that the roofs of people's houses began to fall down on their heads. It seemed that the DDT was also killing a parasitic wasp which had previously controlled thatch-eating caterpillars. Worse, the DDT-poisoned insects were eaten by cats. The cats started to die, the rats flourished, and the people were threatened by outbreaks of sylvatic plague and typhus. To cope with these problems, which it had itself created, the World Health Organization was obliged to parachute 14,000 live cats into Borneo.

"Operation Cat Drop" reprinted courtesy of The Rocky Mountain Institute in Snowmass, Colorado.

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Program Contents

From the days of house-calls, when x-rays were a daring innovation, to the era of high-tech hospitals and specialist physicians, "Matters of Life and Death" tracks the passion and determination of medical work in the twentieth century. Dramatic experiments, the "politics" of science, and races against the clock form a backdrop to the discovery of new treatments, antibiotics, and advances in surgery and medical technology that have lengthened our lives and caused us to rethink our assumptions about life and death.

Hour 1

Prologue
Pan American Exhibition, 1901

Introduction
Medical science in the age of McKinley

Bubonic Plague
How do we fight disease?
- Plague in San Francisco, 1899
- Public health policy—a product of its time
- War on rats defeats a second epidemic
- New understanding of public health

Pellagra
Prevention versus cure
- Joseph Goldberger seeks causes of pellagra
- Observation and experimentation
- The link between poverty and disease

Diabetes
Living with disease

- Dire treatments for a fatal disease

ANIMATION> Functions of the pancreas
- Frederick Banting and Charles Best's experiments
- Setbacks, successes, and squabbles
- The price of survival

Penicillin
A drug that changes history
- Alexander Fleming's work in WWI
- Fleming's 1929 discovery of penicillin
- Turning a discovery into a cure
- Mass production and massive change

Hour 2

Introduction
Postwar optimism

Heart Surgery
Another medical barrier collapses
- Daring heart experiments in WWII
- New procedures help surgeons beat the clock
- Heart-lung machine opens new possibilities

Organ Transplants
New solutions, new dilemmas
- Fighting rejection—the road to transplants
- Doctors face new doubts and pressures
- First heart transplant, 1967
- Success and its side effects

Cancer
Growing knowledge of an old enemy
- Increased lung cancer raises questions
- Smoking and other carcinogens
- Treatments—chemotherapy and childhood leukemia
- Scientists find cancer-controlling genes
- Search for root causes

The Role of Modern Medicine
Worldwide challenges

- Guinea worm parasite
- Health in developing nations
- The aging population

Conclusion
Using twentieth-century knowledge

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Activities

Public Health Task Force

Overview Research a disease and suggest ways to prevent its spread

Learning Goal Appreciate the complexity of public health planning

Video Link Bubonic Plague

Present the video segment on the plague outbreak in San Francisco. Ask students to note the strategies health officials undertook to try to stop the epidemic. After viewing, discuss these strategies with students. Were they effective? Why or why not? What could officials have done differently?

Today, infectious diseases have reemerged as worldwide threats to public health. Have individuals choose a health threat that interests them from the list below. Group students accordingly. Each group forms a task force to research and advise the government on ways to halt the disease. Teams need to find out when the disease was identified and how many people it has infected. What are its symptoms? How does it spread? How can it be prevented or treated? What social, economic, or environmental factors contribute to its spread?

After completing its research, each task force should prepare at least three recommendations to the government for limiting the spread of the disease. These could include changes to laws, spending on research, public awareness ads, or other measures. Students may think of familiar campaigns (such as anti-smoking) as potential models. After the task forces present and explain their recommendations to the class, encourage questions. For example: How will strategies be implemented? What are possible drawbacks? How can recommendations balance individual rights and the public welfare?

End-of-Century Health Threats

HIV/AIDS	tuberculosis
Lyme disease	hantavirus
meningitis	rabies
yellow fever	cholera
malaria	diphtheria
Ebola fever	Lassa fever
Creutzfeldt-Jakob disease	
antibiotic-resistant bacterial infections	

In Dangerous Times

Overview Conduct an oral history interview about polio

Learning Goal Discover how medical advances have changed people's lives

Video Links Penicillin, Hour 2 Introduction

Medical developments have made some devastating diseases things of the past, or manageable enough to live with. Ask students to record an oral history on the polio epidemic. Each student should interview an adult who can recall the period before the polio vaccine was available (pre-1953). Before the interviews, help students generate ideas for questions, such as: Did people worry about getting polio? How did they try to protect themselves or their children against it? Did you know anyone who contracted polio; if so, what happened? What do you remember most about those times?

Later, provide an opportunity for students to share what they've learned. If any students taped (video or audio) their interview, they may want to play a portion for the class (with the subject's permission). Have students note similarities in interviewees' experiences, and draw conclusions about the epidemic. Discuss with students how their own lives might have been different if the polio vaccine and other "miracle drugs" had not been developed. The video segment on penicillin can enrich this discussion. Make sure students understand that the polio vaccine prevents an illness, while antibiotics like penicillin treat illnesses.

What Happens When...?

Overview Brainstorm a concept web on longer life span

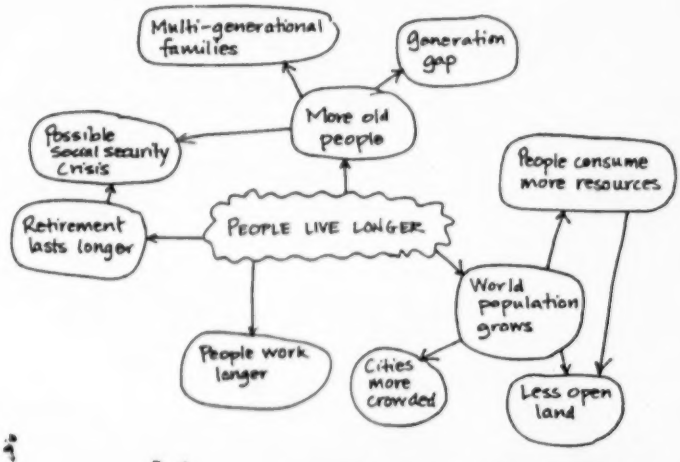
Learning Goal Explore the consequences of prolonging life

Video Link The Role of Modern Medicine

Medicine's modern accomplishments allow more people to live longer than ever before. As this happens, world population tends to rise. Students can use a "futures web" to identify some potential consequences.

Write the concept "People live longer" on the board. Ask students to think about the impact this might have on people, society, and resources. You can suggest the first idea—for instance, "World population grows"—to start the process. Write your concept on the board, and draw an arrow connecting it to the central concept. Invite students to continue adding to the web. Entries may be positive, negative, or neutral, and link to the central concept or to concepts that others have contributed. For each new concept, students should indicate cause-and-effect relationships with arrows (see sample web below). Make sure students can explain connections they propose. When everyone has had a chance to contribute, review the web, offering time to discuss and debate the proposed consequences.

View the final segment of "Matters of Life and Death." Discuss the issues covered; then revisit the web and let students make additions or amendments.



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In-depth Investigation

Disease Detectives

Overview Simulate the spread of a disease and locate "patient zero"

Learning Goal Understand some factors that affect the spread of disease and the challenges of epidemiology

Video Links Bubonic Plague, The Role of Modern Medicine

Introduction
From bubonic plague to AIDS to Guinea worm parasite, scientists and public health officials have struggled to understand and contain the spread of infectious diseases. Using common laboratory equipment, students can simulate the spread of a simple imaginary disease in order to explore some factors that affect the rate of infection and the difficulties in tracing the path of transmission. Following the activity, have students view one or both of the video segments and discuss the importance of tracing an infection's roots.

Procedure 1

Simulating an Epidemic
Materials:
- test tube and dropper for each student
- distilled water
- 0.1 molar NaOH
- phenolphthalein solution, dissolved in alcohol and diluted in water (pH indicator)

1. Let students know they are going to model the transmission of a disease by exchanging some of their test tubes' contents with that of other students. Mention that one of the test tubes is "infected" with an imaginary infectious disease. (Prepare the test tubes prior to class: Fill one tube halfway with 0.1 molar NaOH; fill the rest of the tubes halfway with distilled water.)
2. Distribute prepared test tubes and droppers randomly to the class. Make a mental note of who receives the test tube containing NaOH.
3. Have students walk around the room with the test tubes. When you say "Stop!" each student should use a dropper to trade a drop of fluid with the person nearest them. Repeat until at least three trades have occurred.
4. Now it's time to test for the imaginary infection. Put a drop of phenolphthalein in each test tube. If the fluid turns pink, the test tube is "infected" with NaOH. How many students are now "infected"?

Caution Sodium hydroxide and phenolphthalein can irritate the eyes and skin. Avoid contact. Avoid spilling

Procedure 2

Tracing the Source of Infection

1. Now that a portion of the class has been "infected," put students in the role of epidemiologists. Their challenge is to collect data that will help them trace the path of the epidemic and locate the original carriers.
2. As a class, use the data to try to deduce which individual was the original carrier of the disease. Why might it be important to locate the source of infection? What difficulties arise in trying to collect and interpret data? Note that the simulated disease has a 100% rate of infection that appears immediately under testing. Some diseases, such as AIDS and chicken pox, can remain dormant in the body for a long time. Others, such as Ebola, kill the host rapidly. How might each of these factors affect the spread of disease and the ability to identify carriers?

9

The Value of Discovery

PENICILLIUM MOULD

FROM PROFESSOR ALEXANDER FLEMING 1935

One of the greatest discoveries in the fight against infectious disease was penicillin. Alexander Fleming, who found the mold that later became penicillin, saved a sample of the original mold. He eventually gave it to a colleague at St. Mary's Hospital in London. That colleague died in 1970, and his son recently auctioned off the sample for a surprising $25,300 to the Science Museum in London!

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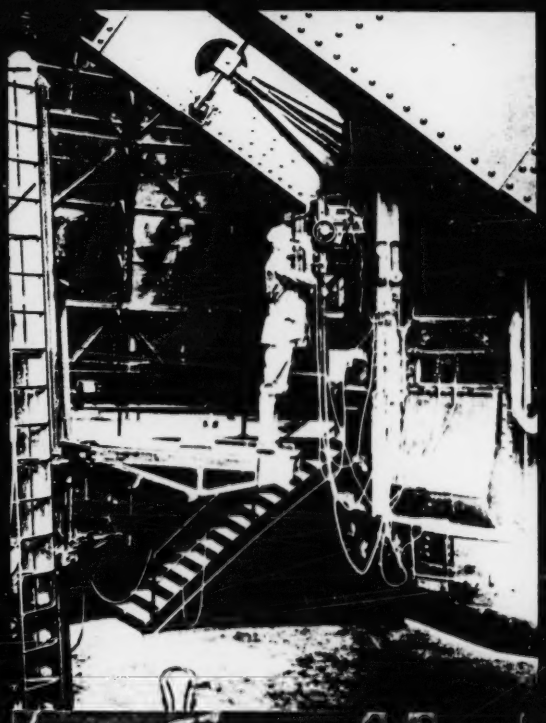
For expectations and outcomes, see page 30.

The atom split! The universe in motion! Matter is mostly empty space, and space is full of dark matter! These confounding ideas throw the centuries-old view of a stable and predictable world out the window. Twentieth-century discoveries in physics and astronomy reveal the cosmos as a dynamic universe whose origins and destiny we struggle to understand, and whose extremes of size – from the fleeting existence of subatomic particles to the mind-boggling expanses of time and space – we can barely fathom. As the century unfolds, physics and astronomy become more and more entwined, inspiring the search for a "grand unified theory" to explain simply everything.



Mysteries of the Universe

In scientific investigations, failure can be as important as success.

Shifting Certainties

"Results! Why man, I have gotten a lot of results! I know several thousand things that won't work." So stated inventor Thomas Edison. And it's true in most any field: failure makes you rethink your approach, question your assumptions, and try again. And sometimes theories and assumptions that turn out to be flawed are crucial in helping us get to some other knowledge.

"Now, if we run our picture of the universe backward several billion years, we get an object resembling Donald Duck. There is obviously a fallacy here."

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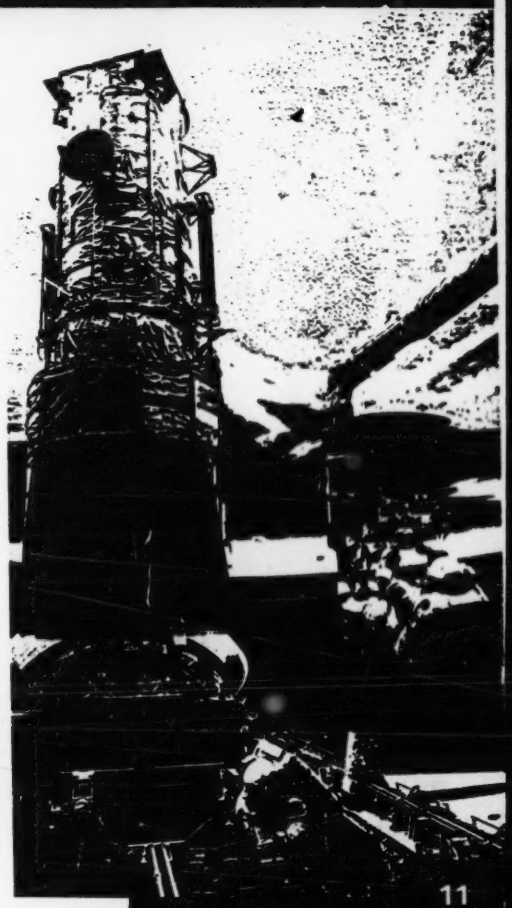
Program 2
Premieres January 12, 1998

Program Contents



In 1900, like today, the everyday world seemed to follow Newton's laws of physics. But from the opening days of the century, discoveries about the hidden workings of that everyday world suggest all is not as it seems. Quantum theory, relativity, nuclear power, and clues about the birth and death of the universe have rocked our deepest beliefs. "Mysteries of the Universe" brings us close to the men and women—with their ambitions, intuitions, talents, and faults—whose work forever altered astronomy and physics.

Hour 1

Prologue
Halley's Comet

Introduction
The lure of the heavens

New View of the Universe
New technology offers new evidence
- George Hale builds world's largest telescopes
- Mt. Wilson Observatory
- Henrietta Leavitt's "yardstick to the universe"
- Edwin Hubble redefines the universe

ANIMATION> Red shift shows universal expansion

The New Physics
Redefining space, time, and gravity

- Albert Einstein questions Newtonian physics
- Special Relativity

SIMULATION> $E=mc^2$

- General Relativity

ANIMATION> Time and space are curved

The Nature of Matter
New evidence requires new theories
- Portrait of Niels Bohr

ANIMATION> Changing model of the atom
- Implications of the nucleus
- Bohr adds quantum theory to the model
- The electron and the uncertainty principle

DEMONSTRATION> Single-slit experiment
- Resistance to quantum mechanics

Effects of War
World events shape the course of physics
- Is the nucleus the ultimate piece of matter?
- Europe's scientists flee fascism
- Splitting the atom
- Manhattan Project

Hour 2

Introduction
Lifting the veil from the face of the universe

Beyond the Visible Universe
New stars and physics

- Strange radio signals from space

ANIMATION> Death of a star
- Black holes—theory and imagination

ANIMATION> Evidence of a black hole
- Current theory

Cosmology
Did the universe have a beginning?
- The big bang theory
- How to prove the big bang
- An accidental find

ANIMATION> Evolution of the universe

The Heart of Matter
Search for simplicity makes things complicated
- "Elementary" particles proliferate
- Quest for quarks
- Is there a fundamental force?
- The superconducting supercollider
- Strings—physics turns to math

ANIMATION> How strings might look

New Frontiers
Views of what's out of sight
- Calculating the mass of the cosmos
- The universe's fate
- Dark matter—the "real" universe?

Conclusion
Experiencing the mysterious

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Activities

Looking Back in Time

Overview Calculate time for sunlight to reach Earth and consider other time-based distance measurements

Learning Goal Understand that light takes time to travel

Video Link New View of the Universe

How do astronomers discover the history of the universe? What we detect in the night sky is essentially a snapshot of the past.

To illustrate this concept, ask students when they think they would see the Sun "go out" if it were extinguished at exactly 12 noon. Remind them that the Sun is 150 million km away and that light travels about 300,000 km per second. (Earthlings would see the Sun vanish at about 12:08 p.m.)

To explore why we see a delayed image, brainstorm other examples or analogies of delay in transmission time. For example, after you shut off the faucet, water still pours out of a garden hose for a few seconds.

Ask students how far light would travel in a year if it takes eight minutes to go 150 million km. That distance, 9,450,000,000,000 km, is a light-year. Why would people invent this measure of distance?

Brainstorm examples from students' experience of using time to measure distance (e.g., a 15-minute walk to school). Invite students to invent other speed-time units to measure distance—a slug-minute, for example. What problems could this method have? (A particularly energetic slug would throw you off.) Discuss how the constancy of light's speed makes light-years extremely accurate. This exploration of light and distance can help students grasp the magnitude of Edwin Hubble's discoveries, seen in the New View of the Universe video segment.

Atomic Ethics

Overview Analyze statements of Manhattan Project scientists

Learning Goal Grasp ethical complexity of scientific research

Video Link Effects of War

As students watch this video segment that covers the Manhattan Project, have them note the mood at Los Alamos. Afterwards, ask them whether they would have enjoyed being part of the project. Why or why not?

Have students generate two lists of words—positive and negative—to describe the scientists' feelings about this project.

Then, hand out copies of the readings on page 26. After students have read these excerpts written by Manhattan Project scientists, discuss questions such as:

How did different scientists feel about working on the bomb? What ethical problems did the project's secrecy pose for some? Have students compare the points of view on moral responsibilities of scientists. Whose arguments do they find most persuasive, and why? With whom do they think Phillip Morrison (interviewed on the video segment) would agree? Encourage students to add new words to their lists.

Ask students to consider Oppenheimer's statement, "If you are a scientist, you cannot stop such a thing." For example, if scientists realize they have the capability of creating biological weapons or cloning humans, does that mean they should do it? Why or why not? What responsibility, if any, should scientists bear for the results of their research?

Stranger than Fiction?

Overview Analyze science fiction films as reflections of attitudes toward science

Learning Goal Appreciate the impact of science on the popular imagination

Video Link Beyond the Visible Universe

By taking current scientific knowledge and adding a twist of imagination, science fiction movies reflect our hopes and fears.

Show students the video segment, in which a spaceship crew from the British television show *Blake's 7* (1980) discovers that its spaceship is "falling into a black hole."

Then, ask students to brainstorm other science fiction movies or TV programs that deal with travel in space. What characteristics do they share with *Blake's 7*? What problems with space travel have been overcome, and how? What problems have been overlooked? How do the films play upon fears about new scientific discoveries?

To further explore what science fiction reveals about our attitudes toward science, have students choose a sci-fi movie from any time period and prepare a two-minute synopsis to share with class. In addition to the synopsis, students should mention when the film was made and describe what knowledge and technology it presents as new. They should also address questions such as: What scientific principle was at the heart of the plot and how might the audience have felt about it? How was science going to save or ruin people? How were scientists portrayed? Suggest that students look for political and social issues addressed through the science fiction.

After students' presentations, ask students to form generalizations about movies from the same decade.

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In-depth Investigation

Universal Proportions

Overview Create scale models of Earth, the Moon, and distances in space

Learning Goal Develop a sense of the relative sizes of Earth, the Moon, and of the immense distances within the universe

Video Link New View of the Universe

Introduction

When Edwin Hubble calculated the distance to a variable star, he was astounded to see that it was outside the Milky Way. The universe was far larger than anyone had expected! To give students an idea of the immense size of the universe, have them work in groups of three to model the relationship between Earth and the Moon, and then scale distances within and beyond our solar system. After the activity, show the New View of the Universe video segment so that students can learn more about the people and events that revolutionized our understanding of the universe.

Procedure 1

Model the Earth and Moon

Materials for each group:
- three 8 oz. cans of clay (rolled into one ball)
- measuring tape or yardstick
- toothpicks

1. Give each group a ball of clay, and ask students to divide it into 51 equal pieces. Allow time for students to figure out how to divide the clay.

2. Have students draw upon their existing knowledge to create scale models of Earth and the Moon using the 51 pieces of clay. Students should record how many pieces they use to build each model. Have them record the volume ratio of Earth to the Moon using the number of clay pieces in each model. Compare results.

3. Explain that Earth is about 50 times the size of the Moon, based on its volume. Ask students to regroup the clay in a 50:1 ratio. How do their original models compare in volume to this ratio?

4. Now that the models accurately show the relative sizes of Earth and the Moon, ask students to show the relative distance between them. Again, encourage them to use their own intuition and knowledge to decide how far apart to place their models. Have each group measure and compare distances, and discuss their reasoning.

5. The mean distance between Earth and the Moon is 384,000 km, and Earth's diameter is 12,756 km. Have students use this information to figure out how far apart to place their models to represent the relative distance between Earth and the Moon. How close were their original estimates?

6. The space shuttle orbits at approximately 611 km above Earth. Have students locate the shuttle's orbit based on the scale of their clay models. A toothpick inserted into the clay can show the distance of the shuttle from Earth.

7. Where does the Sun fit in this scale model? Let students know that the mean distance between the Sun and Earth is about 150,000,000 km. Ask students to determine the proper placement of a marker representing the Sun. Would the Sun model be in the classroom?

Procedure 2

Scale Distances

Materials for each group:
- butcher paper
- measuring tape or yardstick
- copy of chart below

1. The distance from Earth to the Moon is minuscule compared to distances within our solar system and beyond. Give each group a piece of butcher paper (about 1.25 m long) and a copy of the chart below. Have each group create a scale drawing of the solar system showing the relative distance of each planet from the Sun.

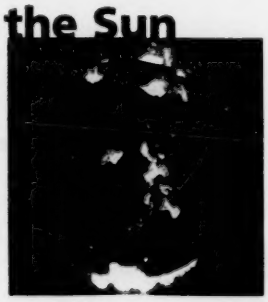
2. When students are finished, have each group explain its scale. With that scale, can they show the position of the Moon? If not, what scale would work? Then how far away from the Sun would Pluto be?

3. Finally, have each group use the scale it established to calculate the length of paper needed to show the distance from the solar system to Alpha Centauri, the nearest star system, 4.3 light-years away; from the Sun to the center of the Milky Way, 30,000 light-years away; and from our galaxy to the Andromeda nebula, the nearest spiral galaxy, 2 million light-years away.

13

Mean Distance from the Sun

Mercury	58 million km (36 million mi)
Venus	108.2 million km (67 million mi)
Earth	150 million km (93 million mi)
Mars	227.9 million km (140 million mi)
Jupiter	778.4 million km (483 million mi)
Saturn	1.4 billion km (886 million mi)
Uranus	2.9 billion km (1.8 billion mi)
Neptune	4.5 billion km (2.8 billion mi)
Pluto	5.9 billion km (3.7 billion mi)



For expectations and outcomes, see page 30.

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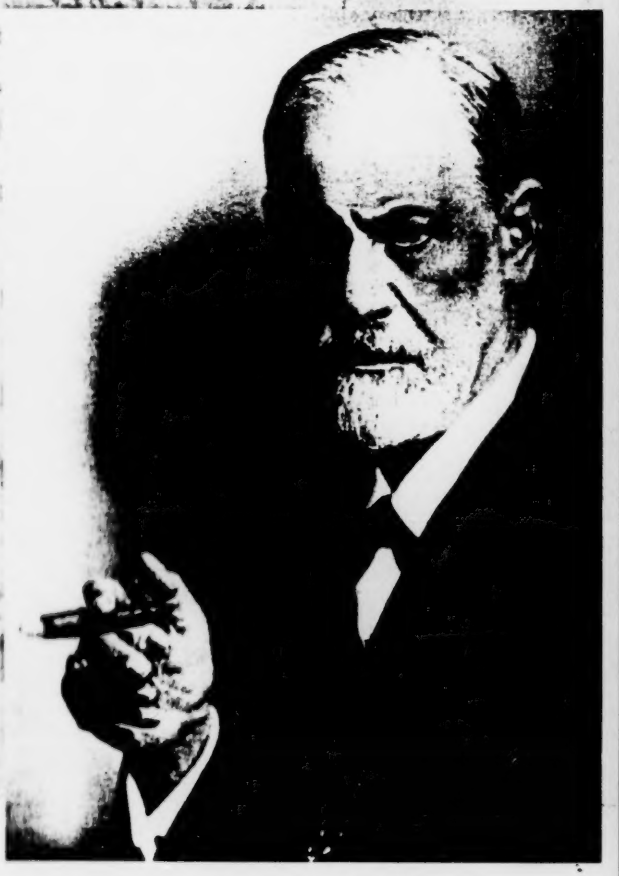
Nothing yet has shaken human beings' conviction that we are special. Not the knowledge that the universe is 15 billion years old, nor that it holds 100 billion galaxies. Not the discovery that we evolved from other primates, nor that our DNA differs from some modern apes' by less than 2 percent. Yet throughout the century, scientists have asked: How do we know what we know? How do we become who we are? Can we solve the mystery of human behavior and harness the forces that govern it? Of all things in the universe, we may be the hardest to understand.



In Search of Ourselves

Science cannot be separated from its historical, cultural, and social contexts.

Performance Enhancement

Applied psychology has become one of the most visible sciences this century—in the form of advertising. It's where the study of human behavior and the art of business meet. This century's increasing knowledge of human behavior has been matched by increasingly sophisticated (or just outrageous) ads that apply this knowledge. This 1937 magazine ad gets your attention, and with some double-entendre creates an association between the product and...something else.

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Program Contents

It's all in the genes. Or is it ...? "In Search of Ourselves" traces the pendulum swing of psychological theory from nature to nurture and back again. Case studies, classic experiments, and research on the brain blaze this trail of discovery, revealing what we have learned about ourselves and what still remains a riddle. We also see the dark side of our faith in the perfectibility of human nature, as scientific ideas are twisted to fit political agendas. "In Search of Ourselves" is a story of the lessons learned, as well as the ways which we have learned them. As the century ends, the workings of our minds remain an irresistible frontier.

Hour 1

Prologue
Neurasthenia

Introduction
Why do we think, act, and feel the way we do?

Hysteria
Societal and medical explanations
- A grab-bag of symptoms
- A woman's disease?
- J.M. Charcot blames poor heredity
- Neurologist Sigmund Freud questions Charcot
- Freud's new theory of mind
- Psychoanalysis gains critics and followers

World War I
War trauma puts new theory to the test
- WWI brings shell shock, male hysteria
- Physicians find no causes for symptoms
- Talking cure heals many soldiers

Eugenics vs. Behaviorism
War of ideas
- Army intelligence testing
- Is there a gene for intelligence? Poverty?
- John Watson introduces behaviorism
- Scientific child rearing
- Behaviorism fits the American Dream

Theories in Practice
The downsides
- Eugenicists fear immigrants' genes
- Laws and customs promote "good" heredity
- Genetic research shows eugenics' flaws
- Watson and advertising—behaviorism at work
- Hitler uses behaviorism to promote eugenics

Hour 2

Introduction
Environment theory leads postwar era

Bringing Science Home
Postwar optimism
- B.F. Skinner—operant conditioning
- Behaviorism in education
- Benjamin Spock's baby book
- Harry Harlow—scientific study of love

Psychoanalysis
How powerful is it?
- Frieda Fromm Reichmann's technique
- Case study—Joanne Greenberg

Pills for the Mind
An empirical advancement
- Standard treatment of psychotics
- Chlorpromazine's accidental discovery
- Successful chemical therapy

Understanding the Brain
Why do medications work?
- Brain chemistry
- Neurotransmitters' link to behavior
- A biological breakthrough

A New Synthesis
Environment and biology interact
- Genealogy and genetics
- Colombian family study
- Search for early Alzheimer's gene
- Genes, brain, and environment shape human behavior

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Activities

Testing, Testing

Overview Assess intelligence test questions for bias

Learning Goal Understand roots and flaws of intelligence testing

Video Link Eugenics vs. Behaviorism

Ask students what makes them think somebody is smart or talented. Generate a list of attributes—for instance, verbal or math skills, musical talent, athletic talent, creativity, problem solving, insight. Suppose students had to measure each of these. How would they go about it?

Present the video segment, which starts with a focus on U.S. Army intelligence testing. Then hand out copies of page 27 of this guide. Explain that these are questions from the actual 1917 tests, which determined an individual's role in the army. Picture questions were for people who did not speak English or couldn't read and write.

Ask students to consider the following: Which questions are easiest or hardest? Does this vary among classmates? Are there questions for which more than one answer is possible? What skills and knowledge would a person need to score well on the test? Are some people more likely to score better than others; would a person's education, sex, or cultural background make a difference? Ask students how well they think these questions identify people who would make good military officers. Based on these questions, what kinds of people were most or least likely to become officers? What qualities might be useful in an officer, and how might those be measured? Why is it difficult to design an unbiased test?

For official answers to test questions, see page 30.

Neurologist Wilder Penfield was one of many scientists to try to pinpoint mental functions such as memory to certain parts of the brain. In this photo he has just drawn the brain map simultaneously with both hands!

Conditioning Consumers

Overview Analyze advertisements' methods of affecting behavior

Learning Goal Understand the behaviorist concepts of association and conditioning

Video Links Eugenics vs. Behaviorism, Theories in Practice

Ask students what or who they associate with a particular product—name a brand of athletic shoes, for example, or a certain soft drink or car. If students name a personality, icon, or abstraction to describe the product rather than product features, point out that they are seeing the theory of behaviorism in action. Remind them to keep that in mind as they watch the video segments.

Show the segments, especially the parts on behaviorism. Discuss how John Watson transferred his knowledge of psychology to the business of advertising. What was his concept of "association"? Encourage students to think critically about advertising. Ask them to describe and analyze a current television or magazine advertisement for a report or presentation.

Have students describe the advertisement. What is the product? What happens in the ad? Who is shown using the product and how is it used? Where did students see the ad? Then ask students to analyze whose behavior the ad is attempting to influence, and how. Identify important people or objects and explain their role. What factual information does the ad provide? What is left out? What outcomes does it suggest for those who use (or fail to use) the product? According to the ad, what is most important about the product? Ask volunteers to present their reports to the class. What conclusions can students draw about how advertising attempts to condition consumer behavior?

Brave Old World

Overview Read and analyze part of *Brave New World*

Learning Goal Envision how scientific knowledge becomes social policy

Video Links Eugenics vs. Behaviorism, Theories in Practice

Aldous Huxley's 1932 novel, *Brave New World*, which offers a grim view of a future society shaped by eugenics and behaviorism, provides a good opportunity to discuss these issues.

After showing the suggested video segments, have students read the first two chapters of *Brave New World* (about 30 pages). In a class discussion, ask them to use what they've learned from the video to relate Huxley's vision to the psychological and social theories emerging at the time he wrote the book. What events or developments shown in the video may have influenced Huxley's thinking? What role do eugenics and behavioral conditioning play in the society Huxley portrays? What predictions did he make about how these new theories would influence society? In what ways does the society Huxley envisions resemble our own? In what ways is it different?

Today scientists are learning even more about human genetic makeup and the biology of the brain. Discuss with students how they think applications of new knowledge (for example, fetal testing or genetic engineering) might influence society in their lifetime.

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In-depth Investigation

Memory Lane

Overview Examine some factors that affect short-term memory

Learning Goal Understand that short-term memory decreases quickly over time and that certain factors can increase or decrease recall

Video Links Understanding the Brain, A New Synthesis

Introduction
Advances in technology have enabled scientists to explore questions about the brain that were unanswerable a century ago. PET scans, for example, help researchers identify regions of the brain that are active during specific cognitive tasks, such as memory recall. Students can investigate short-term memory in this activity to examine some factors that increase and decrease recall.

Procedure

Recall Test
Materials:
- paper
- pencil
- clock

1. Announce to students that it's time for a test—of short-term memory! Their challenge is to recall items from a list they will hear twice.

2. Divide the class into four numbered groups. Have each student write his or her group number on a sheet of paper.

3. Read aloud each item from the list (above right). Read slowly and clearly, pausing for several seconds after each item. For nonsense syllables, pronounce each one and then spell it (e.g., "tig: t-i-g"). Shout the word NAV as loud as you can; then spell it in a normal speaking tone. Read the list the same way a second time.

4. Immediately after the second reading, ask students in Group 1 only to write down every item they can remember. Each student should do this independently.

Short-term Memory List

pencil	Lincoln
tig	impose
bex	NAV
Washington	submit
tal	ruj
ruj	53
notebook	fet
bex	

5. Conduct class as usual. Five minutes after the second reading, ask Group 2 students to record all the items they remember. About 15 minutes after the second reading, ask Group 3 to do the same. At the end of class, have Group 4 write down all the items they recall. Collect the lists.

6. At the next class, assemble students into their groups. Return each group's word lists along with the actual list. Ask students to analyze their performance as a group. Have each group find the average number of items recalled and rank the words in order of the frequency of recall. Ask each team to brainstorm factors that might have affected recall.

7. As a class, graph the average number of words recalled by each group against the length of time between reading and recall. Discuss the resulting curve. What does this "forgetting" curve imply about the capacity and persistence of short-term memory?

8. Ask students to compare the groups' rankings of items most frequently remembered or forgotten, and compile a classwide ranking. Why were some items recalled more frequently than others? Consider, for example, the sequence of items on the list. Were items near the beginning, middle, or end more likely to be remembered?

9. Based on this activity, have students develop at least two hypotheses about short-term memory and cite evidence that supports them.

Extension

Meaning enhances memory. One way to make information meaningful is to put it in context. Divide the class in half, and tell only one half the context for the sentences they will all hear: fishing. Read the sentences (see box at right) aloud. When you're done, ask students to write down each one they remember. Then, read the sentences again. Have them check the number they recall accurately (not necessarily word-for-word). Compare responses. How did having a way to mentally organize information affect memory? Why is it so hard to remember a series of unrelated statements? How could students use this principle to improve study habits?

Memory Sentences
Rainy days are better than sunny days. It's hard to find a good place in the city. You'd be surprised what a nuisance seagulls can be. The earlier you get up, the better. Books can't teach you everything. Cleaning is usually pretty messy. If you can't swim, wear a lifejacket. A good book or a radio helps to pass the time. Some people like worms, some like bugs. Lemon juice takes away the smell.

For expectations and outcomes, see page 30.

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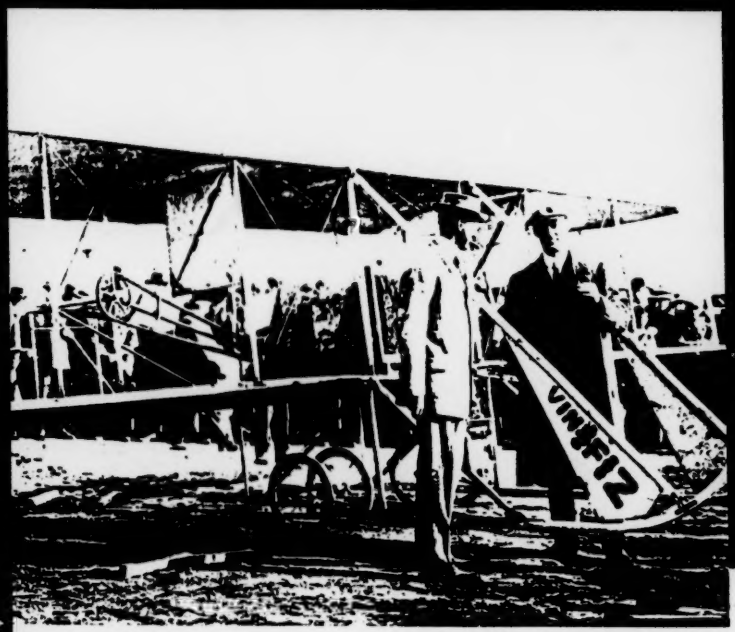
Better, Bigger, Faster

Technology has transformed our lives, our work, and the way we think about the world in the twentieth century. How did it happen? This program traces that revolution from a time of unparalleled enthusiasm for technology to a time of doubt and questioning. Meet the inventors, entrepreneurs, and industrial scientists whose work fueled this technological boom. Trace the development of new technologies and the industries they spawned. And consider the broader social forces—government spending, the Cold War, and the growth of consumerism—that have redefined the role of science in our society.



Science is a human endeavor.

20-20 Hindsight

Humans are dreamers and problem solvers, and these characteristics help drive technology. We can't seem to stop "pushing the envelope," continuing to surprise even ourselves. The contradiction of predictions throughout the decades shows that it's virtually impossible to foresee our technological future.

"Heavier-than-air flying machines are impossible."
William Thomson, Lord Kelvin
Physicist, mathematician, and president of the British Royal Society (c. 1895)

"The horse is here to stay, but the automobile is only a novelty—a fad."
President, Michigan Savings Bank, advising Henry Ford's company lawyer not to invest in Ford Motor Company (1903)

"While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility, a development of which we need waste little time dreaming."
Lee DeForest
Radio pioneer and inventor (1926)

"There is not the slightest indication that [nuclear] energy will ever be obtainable. That would mean that the atom would have to be shattered at will."
Albert Einstein
Physicist (1932)

"Space travel is utter bilge."
Richard van der Riet Wooley
British Astronomer Royal (1956)

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Program Contents

Our technological odyssey starts in a modest, turn-of-the-century home. Inklings of change are apparent, but are the residents prepared for the transformation the coming years will bring? The startling view of humans flying "free from the earth at last" is just an introduction to the surprises ahead. And, each new technological development—whether a car for the masses or a worldwide computer network—brings profound changes to homes across the country and to the lives of the people in them.

Hour 1

Prologue
Past visions of the future

Introduction
What's state-of-the-art in 1900?

Aviation
Competition drives technology
- Airplane wows public at 1910 air show
- Wright brothers stun Europe

ANIMATION> Wing warping for plane stability
- First trans-American flight, 1911
- Political tensions boost European aviation
- Airplanes' role in WWI and beyond

The Automobile
Technology for the masses
- Henry Ford

ANIMATION> Model T design
- The Tin Lizzie's success
- Mass production and consumption
- Impact on society and urban development

Radio
Technology in search of an identity

- From telegraph to sound broadcast
- Commercial radio's origins
- Early programming
- Economics and the rise of radio networks

Faith in Technology's Benefits
The marriage of technology and big business
- Search for the first synthetic material
- Wallace Carothers develops nylon, 1934
- FDR opens 1939 World's Fair
- Corporate world envisions the future

Hour 2

Introduction
War yields new products and incentives

Computers
The military sponsors digital technology

- Early computer technology

ANIMATION> Binary code
- Development of Whirlwind computer
- Air defense network lays path for future

The Space Race
Politics drives technology
- Soviet achievements spur U.S. space program
- Goal: the Moon
- Apollo 8—Can we make it?

ANIMATION> Attaining lunar orbit
- New view of the Moon—and Earth

Technology's Ills
Reassessing the promise of technology
- Unexpected consequences
- Raised expectations

The Internet
Technology for the 21st century
- Personal computers/microprocessors
- Roots of the Internet

ANIMATION> Uniting computer networks
- The World Wide Web
- Cyberspace: hopes and fears

Conclusion
Factors in technology's future

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Activities

Quality, Quantity, and Other Questions

Overview Plan and test a mass-production strategy

Learning Goal Understand characteristics of mass production and hand-crafting

Video Link The Automobile

Show the video segment on auto manufacturing. Ask students to identify Ford's production goals, and determine how he tried to achieve them.

Hand out copies of the origami pattern on page 28*. Let individuals make their own frogs. Note how long it takes them to finish. Next, form teams of five to six students. Tell them that suddenly the demand for these frogs is so enormous that you can't fill orders fast enough. Each team is an engineering unit in your frog factory and needs to devise a way to make frogs as fast as possible with the workers and materials available.

Give teams about 10 minutes to plan a production strategy for a 15-minute test run. When they're ready, give each team fresh paper and start the clock. After 15 minutes, stop production and discuss the outcomes. How many frogs did each team produce? What strategies did teams use, and which ones led to higher production rates? What affected product quality? How did workers feel about their role, compared to when they made their own frogs ? What could be changed to improve product quality, production speed and cost, or worker satisfaction? What do students know about current industry strategies—such as the use of robotics, off-shore labor, or small-team production—that address these challenges? Ask students how their production strategies might apply to other industries. (With that in mind, you may want to show the segment on penicillin production from "Matters of Life and Death.")

* You may substitute almost any product that requires multiple steps to produce.

Evolution or Revolution?

Overview Analyze and research artifacts to identify technological changes over time

Learning Goal Understand dynamics of technological evolution

Video Links Radio, Computers

Show students "artifacts" embodying technological modifications in a field that has changed during the last century. For example, methods for distributing recorded music (78 rpm and 33 rpm records, reel-to-reel and 8-track tapes, cassettes, and CDs) make an interesting series—and they're portable! Discuss with students how the technology changed over time. What was improved or what was lost? What developments prompted the changes? (For example, electric motors, vacuum tubes, magnetic tape, transistors, and lasers all helped change musical recordings.) Can students identify ways their own lives would be different if not for these changes?

Have students research the evolution of a twentieth-century product or technology of their choice. Ask them to use artifacts or images representing their selection at different time periods to present and explain the changes to the class. What future changes in the technology do students anticipate? (You may want to share the predictions from page 18 with students.)

You may also want to show objects that have fallen out of common use in the U.S. (e.g., carbon paper, darning egg, vacuum tube, keypunch card). Have students try to figure out what the object was used for, why they think it is no longer used much, and what, if anything, has replaced it.

Testing the Virtue of Virtual

Overview Research a topic using two techniques

Learning Goal Discover assets and weaknesses of the Internet as research tool

Video Link The Internet

Have the class generate two questions about something students are studying and would like to know more about. They might wonder, Can you predict an earthquake? What's a neutrino? Was Freud crazy? Factual, theoretical, even silly questions will work, as long as an answer can be researched.

Form two teams. For the first question, one team researches the answer using the Internet; the other team uses the library or other sources. For question two, have teams switch research methods. (Give teams the same amount of time for each question.) When they have finished, teams can report on the findings for each question. Discuss possible reasons for any variations in amount or type of information discovered. Also ask students how much time it took to find information they were looking for. Did they communicate with anyone outside the group (e.g., librarian, systems operator)? What problems or frustrations did they run into? What was most satisfying about the research strategies they used? Did students find anything else that interested them during their search? Did they encounter any advertising during their search? If so, how much?

View the video segment about the Internet. Do students think it is an accurate portrayal of the technology they experienced?

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In-depth Investigation

Super Polymers!

Overview Determine the absorbency of sodium polyacrylate

Learning Goal Understand some properties of a polymer

Video Link Faith in Technology's Benefits

Introduction

W.H. Carothers' 1934 invention of nylon launched the era of synthetic materials. Today, synthetic polymers are found just about everywhere—surfboards, medical supplies, cookware, space suits, and more. Students can investigate sodium polyacrylate, a commonly used synthetic polymer found in disposable diapers.

Caution

Sodium polyacrylate is non-toxic, but should be handled with care. It can be harmful if ingested. Avoid getting it into eyes or nasal passages, as it will cause drying and irritation. Discard dry and gelled polymer in the trash, not in the sink. Store dry polymer in a sealed container to keep it from absorbing water vapor in the air.

• Sodium polyacrylate can be purchased from most school science suppliers for about $5 per 25 grams.

Demonstration

To spark student inquiry, compare the absorbency of a disposable diaper to cotton dish towels. Fold two dish towels together to match the area and thickness of a diaper. Have students guess how much water each will absorb. Slowly and uniformly pour 100 ml of distilled water on both the diaper and the towels. Let students touch and describe them, and continue adding water until each stops absorbing. If possible, weigh the two materials before and after the soaking. What accounts for the difference?

Carefully dissect a diaper. Holding the diaper inside a large garbage bag, peel back its outer lining. Pull the filling out of the diaper into the bag. Discard the outer lining. Shred the filling into small bits. Hold the bag shut and shake vigorously. Repeat three times, then discard the filling. Shake the granules into a corner of the bag. Cut off the corner and empty the granules into a paper cup.

Invite a student to slowly add 100 ml distilled water to the granules, and stir. What happens? Make sure all students can see the gel that forms.

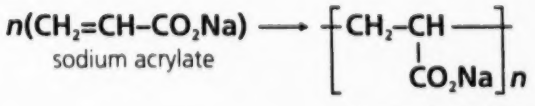
Procedure

Determine Polymer Absorbency

Materials for each group:
- 10 g sodium polyacrylate*
- distilled water
- graduated cylinder
- 10 beakers

Explain that the granules are a superabsorbent polymer called sodium polyacrylate. Have students find out how much distilled water 1 g sodium polyacrylate absorbs. Divide the group into teams and let each one develop its own procedure, or suggest the following:

1. Place 1 g sodium polyacrylate in a beaker. Add 100 ml distilled water; stir, and let stand for a few minutes. Create a chart to record observations (see below).
2. In a second beaker mix 1 g sodium polyacrylate with 200 ml distilled water. Repeat the procedure, increasing the amount of water by 100 ml each time until the polymer no longer absorbs all the water.
3. Students will need to develop a way to judge when saturation occurs. Then, using the volume of the maximum amount of distilled water the polymer absorbed, have students determine the absorbency by calculating the ratio of mass of absorbed water to mass of dry polymer.
4. Have students compare their results and discuss the procedure. What other uses of this polymer can they envision?



sodium polyacrylate

For expectations and outcomes, see page 31.

Sodium polyacrylate	Distilled water	Observations
1 g	100 ml	
1 g	200 ml	
1 g	300 ml	
1 g	400 ml	
1 g	500 ml	

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For centuries, humans have asked: How was Earth formed? Where did we come from? What makes us human? This search for beginnings has led twentieth-century scientists on an astounding journey. From the arctic tundra to Africa's Olduvai Gorge, paleontologists, biologists, and geologists find new clues to the origins of our planet, our species, and life itself. In their quest, they ignite a fierce contest between opposing interpretations of the evidence, a struggle that helps drive science.

Origins

Program 5

Premieres January 15, 1998

Science is a way of asking questions and finding answers.

Light of Our Life?

Studying eyeless shrimp from midocean vents ("black smokers"), oceanographer Cindy Van Dover found a strange, light-sensitive organ in their backs. What's it for, she wondered? The shrimp live without sunlight 3,600 meters below the surface of the Atlantic.

"We began to wonder about other sources of light.... Are 'black smokers' hot enough to emit light visible to the shrimp? [T]he shrimp may indeed be able to see such a glow, even though it might be too dim for a human eye to detect." Testing this hypothesis, Van Dover's team found that vents do glow, raising more questions: Did life and the first photosynthesis begin on the ocean floor?

Meanwhile, more pragmatic questions remained: Were the shrimp good to eat? Only one way to find out. Van Dover's team cooked one. "It did not turn an appetizing pink," she wrote. "If anything, it turned a still more unappealing shade of gray. As we might have expected, given the sulfitic environment bathing the shrimp, the flesh tasted of rotten egg, and, far from being succulent, the texture of the beast was as I imagine a rubber band might be. We concluded there would be no market for these shrimp, even among the most adventurous of the gourmandizing public."

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Quotes from Cindy Lee Van Dover, *Octopus's Garden: Hydrothermal Vents and Other Mysteries of the Deep Sea*. Copyright © 1996 by Cindy Lee Van Dover. Reprinted by permission of Addison Wesley Longman, Inc.

Program Contents

The earthquake that shattered San Francisco, California, in 1906 opens a century of explosive discoveries and debates in the earth sciences. We see Earth through the eyes of Alfred Wegener, struggling to convince the scientific establishment of 1911 that continents do move, and watch as radiodating techniques increase Earth's estimated age—sometimes inspiring skepticism if not outrage. Meanwhile, a parallel upheaval rumbles the life sciences, where new evidence of our primate ancestors and the discovery of DNA's structure stir up controversies of their own. Ancient fossils and living cells give up their secrets to change our view of our species and the mechanics of life.

Hour 1

Prologue
San Francisco earthquake, 1906

Introduction
What do we know about Earth?

Earth's Origins?
New methods and astonishing ideas
- The mystery of Earth's age
- Competing theories, conflicting results

ANIMATION> Radioactive decay
- Alfred Wegener's continental drift theory
- Accumulating evidence

ANIMATION> Pangaea
- Wegener publishes—geologists scoff

Plate Tectonics
A journey to the ocean floor
- Harry Hess finds deep sea trenches
- Discovery of Mid-Atlantic Ridge volcanism

ANIMATION> Sea floor spreading
- Hess suggests mechanism for continental drift
- Ocean floor magnetism

ANIMATION> Magnetic pole reversal
- Earthquakes mark plate boundaries

Human Origins?
A bone of contention
- European and Asian fossil finds
- England's pride—"Piltdown Man"
- Taung skull—a missing link?
- The Scopes trial
- Africa as the cradle of humankind
- "Piltdown Man" proven a hoax, 1953
- "Lucy" and other African finds

ANIMATION> Evolutionary tree

Hour 2

Introduction
What makes evolution work?

Genes and Evolution
Mechanism sought for Darwin's theory
- Mutation, natural selection, and evolution
- T.H. Morgan and his fruit fly experiments

ANIMATION> Mendelian heredity
- Morgan finds genes linked to chromosomes

The Secret of Life
A chemical basis of heredity
- Principal researchers and approaches

ANIMATION>DNA base pairs
- Cracking the code

ANIMATION>DNA's structure
- Significance of the discovery

ANIMATION>DNA replication
- The unity of life

Life's Origins?
Questions, clues, and theories
- A warm little pond?
- Sparking life from non-living material
- Deep sea vents—life without sun
- Meteoric theories of life and death

Conclusion
- Where natural laws meet random chance

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Activities

The Long View

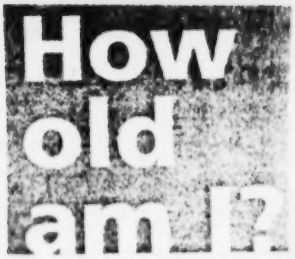
Overview Plot estimates of Earth's age on a time line

Learning Goal Realize how estimates of Earth's age increased with new technologies

Video Link Earth's Origins?

Students can sense the magnitude of change in estimations of Earth's age by making a graph with string and tape. Affix a strip of tape (about 1 m long) vertically to a suitable wall. Mark off the years 1600 to 2000 to create a time line. Divide the class into small groups and give each a historic estimate of Earth's age from those at the right. Have students cut a piece of string to represent their historic estimate of Earth's age (let 4 million years = 1 cm). Then, have students tape the string to the time line horizontally at the appropriate date and add the written description. (Note: The group with Ussher's estimate will find that it cannot even be shown using the given scale. Have these students try to represent 5,662 years in a different way. The group with the most recent estimate will need nearly 12 m of string; they may have to tape it into a corner and onto the next wall.)

Ask students why people might have once thought Earth was so much younger. What changes in science, technology, or society might have encouraged scientists to question Ussher's estimate? Students can research methods used by different scientists, and enter relevant information on the time line. If they discover other estimates of Earth's age from that 400-year period, they should enter them as well.



Estimates of Earth's Age

1658 Bishop James Ussher publishes calculations, based on biblical accounts, that Earth's history began in 4004 B.C.E.

1897 Lord Kelvin argues that Earth is between 20–40 million years old, based on the rate at which he believes Earth cooled from a molten state to its present temperature.

1900 John Joly figures that if sodium washes into the oceans at a steady rate, the proportion of sodium in the oceans shows that Earth is 90–100 million years old.

1907 B. B. Boltwood applies knowledge of radioactive decay rates to estimate the age of Earth at 2.2 billion years.

1913 Arthur Holmes uses radioactive dating to show that Earth is 4 billion years old.

1953 Clair Patterson analyzes meteorites to determine that Earth is 4.65 billion years old.

Seeing and Believing

Overview Research and discuss two early fossil finds

Learning Goal Understand cultural assumptions' influence on scientists' conclusions

Video Link Human Origins?

"If I hadn't believed it, I wouldn't have seen it!" goes one wry saying about paleoanthropology. In 1925, many scientists rejected the newly discovered Taung fossil as a human ancestor because it challenged their beliefs about human history. Show the Human Origins video segment. To guide students' viewing of the video, ask them to note what ideas the Taung fossil challenged. What new theories did it suggest?

To investigate how cultural assumptions can influence scientists' conclusions, have students compare scientists' reactions to the Taung Child and Piltdown Man. After they view the video, ask students to describe the Taung skull. How old was it? Where was it found? Which of its features were apelike and which human? How did this compare to the Piltdown fossil? Invite students to explain why many scientists preferred to see it rather than the Taung Child as a human ancestor. Can students think of other examples of science or society being resistant to new ideas? How can science reinforce social values or personal beliefs? How may it encourage people to question values and beliefs?

DNA "Fingerprinting"

Overview Analyze DNA "fingerprints" to solve a hypothetical paternity case

Learning Goal Interpret visual information to deduce patterns of inheritance

Video Link Life's Origins?

Many students may know about DNA fingerprinting, one application of the discovery of DNA's structure. Today, scientists use DNA "fingerprints"—genetic sequences that vary from person to person—to observe and track patterns of inheritance. Scientists have identified about 2,000 of these variable DNA sequences. By comparing the lengths of selected sequences among individuals, they can establish paternity, track the inheritance of genetic disorders, or even solve crimes.

Students can take on the role of scientists by analyzing the DNA fingerprints on page 29 to solve a paternity case. Students should (1) look for evidence that would determine the possibility that the alleged father is related to the child and (2) justify their conclusions.

For results for this activity, see page 31.

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In-depth Investigation

The Dating Game

Overview Simulate radioactive decay and determine half-life

Learning Goal Understand half-life and its use in determining the age of materials

Video Link Earth's Origins?

Introduction

The discovery of radioactivity allowed scientists to develop new methods of determining Earth's age, with astonishing results. Our planet is far older than people had thought! Students can understand the mechanism of radioactive half-life and how it helps determine age by experimenting with pennies, dice, and sugar cubes to simulate the radioactive decay of different isotopes.

A radioactive isotope's nucleus is unstable and decays spontaneously, giving off radiation and changing into a different isotope. The rate at which nuclei decay is constant. Half-life describes the interval of time during which half of the original atoms decay.

Procedure 1

Simulate Radioactive Decay

Materials for each group:

- shoe box with lid
- 80 pennies, 80 dice, or 80 sugar cubes
- 80 paper clips
- graph paper
- marker

1. Give each group a shoe box and one set (80) of either pennies, dice, or sugar cubes. Explain that the pennies, dice, and sugar cubes represent atoms of different radioactive isotopes. The boxes symbolize rocks containing those isotopes. Each team's mission is to determine the half-life of their isotope. Make sure at least one group is assigned to each of the materials. Sugar cubes should all be marked on one surface with the marker.

2. Share with students the following steps for simulating decay of their isotope. (You may want to model the procedure once.)

- Create a chart similar to the one below.

Trials	Decayed atoms	Undecayed atoms
1		
2		
3		
4		
5		

- Cover box and turn over twice.
- Remove all radioactive atoms that have decayed. These are represented by pennies that show heads, sugar cubes with the marked side face up, or dice showing a 1 or 2. Record number on chart.
- Replace "decayed atoms" with paper clips to represent stable daughter atoms which the radioactive atoms have changed into.
- Record number of pennies, sugar cubes, or dice (the undecayed atoms) that remain.
- Repeat the steps until all pennies, sugar cubes, or dice have been replaced with paper clips.

3. Have teams use their charts to find their isotope's half-life. A half-life is a measure of the average lifetime of a radioactive substance, and specifies the time it takes for one-half of the original atoms to decay. Here, time is represented by trials. How many trials does it take for half of the original 80 atoms to decay (be replaced by paper-clip daughter atoms)? After half (or 40) of the atoms are replaced, how many trials does it take for half of the remaining atoms to decay? Students should record these numbers and continue finding the number of trials it takes to remove half the atoms, until all have decayed.

4. Students should average the numbers of trials determined in step 3. Half-lives of actual isotopes are constant lengths of time. In this model, the number of trials per half-life might vary.

5. Determine a theoretical age for the shoe-box specimen: If each trial represents 1,000 years, what is the isotope's half-life in years?

6. Students can graph their data to illustrate their isotope's rate of decay. Plot the number of trials (representing years) on the horizontal axis and the number of undecayed atoms on the vertical axis. Compare and discuss graphs for different isotopes. How are the curves similar and different? What do the curves suggest about the rate of radioactive decay in general?

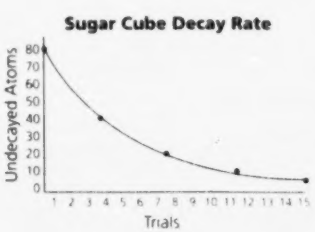
Procedure 2

Date with Half-Lives

1. Groups can challenge each other to determine the "age" of a box containing their isotope, based on the half-life they established. First, each group should assign the number of years a trial represents (such as 1 trial equals 1,000 years) and choose an age for the "rock" the box represents.

2. Have students fill the box with the appropriate number of radioactive atoms and stable daughter atoms to represent the age of their rock.

3. Have groups exchange boxes and half-life information. Ask each team to calculate the age by comparing the ratio of the original radioactive atoms to daughter atoms.



For expectations and outcomes, see page 31.

Readings on the Manhattan Project

In July 1945, Leo Szilard, a physicist working on the atomic bomb, circulated a petition among his Manhattan Project colleagues. It asked President Truman not to use the bomb on Japan without first giving Japan the opportunity to surrender. The following is an excerpt from a letter requesting signatures on the petition.

However small the chance might be that our petition may influence the course of events, I personally feel that it would be a matter of importance if a large number of scientists who have worked in this field went clearly and unmistakably on record as to their opposition on moral grounds to the use of these bombs in the present phase of the war.

Many of us are inclined to say that individual Germans share the guilt for the acts which Germany committed during the war because they did not raise their voices in protest against those acts. Their defense that their protest would have been of no avail hardly seems acceptable, even though these Germans could not have protested without running risks to life and liberty. We are in a position to raise our voices without incurring any such risks....

The fact that the people of the United States are unaware of the choice which faces us increases our responsibility in this matter since those who have worked on "atomic power" represent a sample of the population and they alone are in a position to form an opinion and declare their stand.[1]

The design and building of Manhattan Project bombs took place at Los Alamos, New Mexico. Edward Teller, another physicist there, refused to circulate Szilard's petition. In a letter to Szilard, he explains why.

First of all, let me say that I have no hope of clearing my conscience. The things we are working on are so terrible that no amount of protesting or fiddling with politics will save our souls.... But I am not really convinced of your objections.

Our only hope is in getting the facts of our results before the people [i.e., demonstrating the bomb]. This might help to convince everybody that the next war would be fatal. For this purpose, actual combat use might even be the best thing. And this brings me to the main point. The accident that we worked out this dreadful thing should not give us a responsibility of having a voice in how it is used. This responsibility must in the end be shifted to the people as a whole and that can be done only by making the facts known. This is the only cause for which I feel entitled in doing something: the necessity of lifting the secrecy at least as far as the broad issues of our work are concerned.[2]

Atomic bombs were dropped on two Japanese cities in August 1945. In November 1945, J. Robert Oppenheimer, director of the Los Alamos facility, gave a speech to scientists who had worked on developing atomic weapons. The following is an excerpt from his speech.

In considering what the situation of science is, it may be helpful to think a little of what people said and felt of their motives in coming into this job.... There was in the first place the great concern that our enemy might develop these weapons before we did, and the feeling—at least, in the early days, the very strong feeling—that without atomic weapons it might be very difficult, it might be impossible, it might be an incredibly long thing to win the war. These things wore off a little as it became clear that the war would be won in any case. Some people, I think, were motivated by curiosity, and rightly so; and some by a sense of adventure, and rightly so. Others had more political arguments and said, "Well, we know that atomic weapons are in principle possible, and it is not right that the threat of their unrealized possibility should hang over the world. It is right that the world should know what can be done in their field and deal with it." ...And there was finally, and I think rightly, the feeling that there was probably no place in the world where the development of atomic weapons would have a better chance of leading to a reasonable solution, and a smaller chance of leading to disaster, than within the United States. I believe all those things that people said are true, and I think I said them all myself at one time or another.

But when you come right down to it the reason that we did this job is because it was an organic necessity. If you are a scientist, you cannot stop such a thing. If you are a scientist you believe that it is good to find out how the world works; that it is good to find out what the realities are; that it is good to turn over to mankind at large the greatest possible power to control the world and to deal with it according to its lights and its values.[3]

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[1] From *Leo Szilard: His Version of the Facts, Selected Recollections and Correspondence*, Spencer R. Weart and Gertrude Weiss Szilard, MIT Press, 1978.
[2] See note 1 above.
[3] From *Robert Oppenheimer: Letters and Recollections*, Alice Kimball Smith and Charles Weiner, Harvard University Press, 1980.

Sample Army Intelligence Test, 1917

These are real questions from tests used by the U.S. Army during WWI to measure intelligence of recruits.

TEST 3

This is a test of common sense. Below are sixteen questions. Three answers are given to each question. You are to look at the answers carefully; then make a cross in the square before the best answer to each question, as in the sample:

SAMPLE
Why do we use stoves? Because
- ☐ they look well
- ☒ they keep us warm
- ☐ they are black

Here the second answer is the best one and is marked with a cross. Begin with No. 1 and keep on until time is called.

1 Cats are useful animals, because
- ☐ they catch mice
- ☐ they are gentle
- ☐ they are afraid of dogs

2 Why are pencils more commonly carried than fountain pens? Because
- ☐ they are brightly colored
- ☐ they are cheaper
- ☐ they are not so heavy

3 Why is leather used for shoes? Because
- ☐ it is produced in all countries
- ☐ it wears well
- ☐ it is an animal product

4 Why judge a man by what he does rather than by what he says? Because
- ☐ what a man does shows what he really is
- ☐ it is wrong to tell a lie
- ☐ a deaf man cannot hear what is said

5 If you were asked what you thought of a person whom you didn't know, what should you say?
- ☐ I will go and get acquainted
- ☐ I think he is all right
- ☐ I don't know him and can't say

9 Why do many persons prefer automobiles to street cars? Because
- ☐ an auto is made of higher grade materials
- ☐ an automobile is more convenient
- ☐ street cars are not as safe

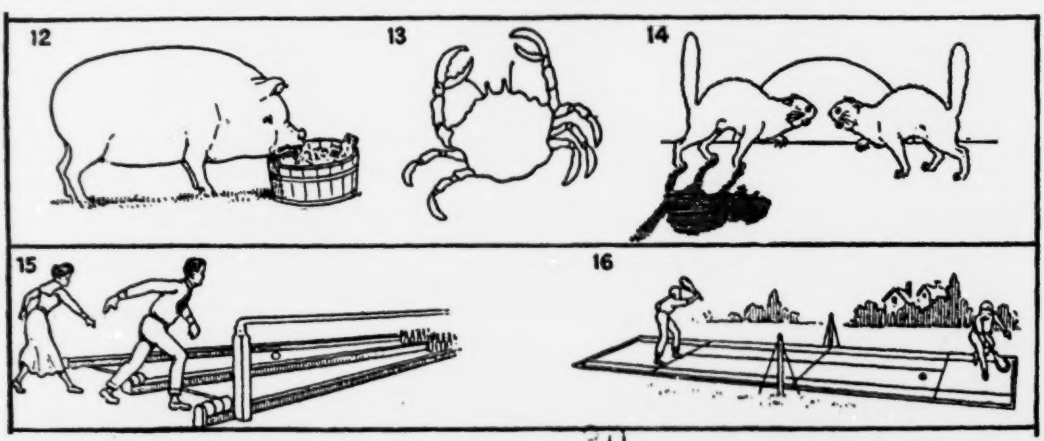
10 The feathers on a bird's wings help him to fly because they
- ☐ make a wide, light surface
- ☐ keep the air off his body
- ☐ keep the wings from cooling off too fast

11 All traffic going one way keeps to the same side of the street because
- ☐ most people are right handed
- ☐ the traffic policeman insists on it
- ☐ it avoids confusion and collisions

12 Why do inventors patent their inventions? Because
- ☐ it gives them control of their inventions.
- ☐ it creates a greater demand
- ☐ it is the custom to get patents

13 Freezing water bursts pipes because
- ☐ cold makes the pipes weaker
- ☐ water expands when it freezes
- ☐ the ice stops the flow of water

If you didn't speak English or couldn't read, you were given picture tests. Draw in what is missing in each picture.



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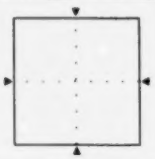
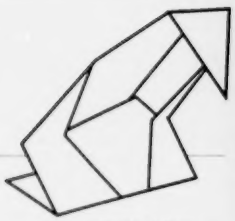
Jumping Frog Folding Instructions

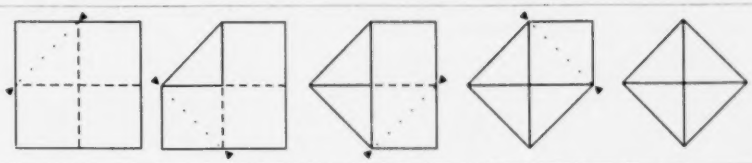
1. Start with a square piece of paper. Fold it in half vertically; crease and unfold. Then fold it in half horizontally; crease and unfold.





Finished Frog

2. Fold each corner into the center.



3. Fold the top left edge so that it meets the center crease. Repeat with the top right edge.

4. Fold the bottom point at the dotted line to form a triangle.

5. Fold the left corner into the center crease. Repeat with the right corner.

6. Fold the bottom edge up along the dotted line shown.

7. Fold the same edge again, this time down along the dotted line shown.

8. Fold the top point down along the dotted line shown.

9. Turn the form over. To make the frog jump, press down on the frog's back, slide your finger back, and let go!

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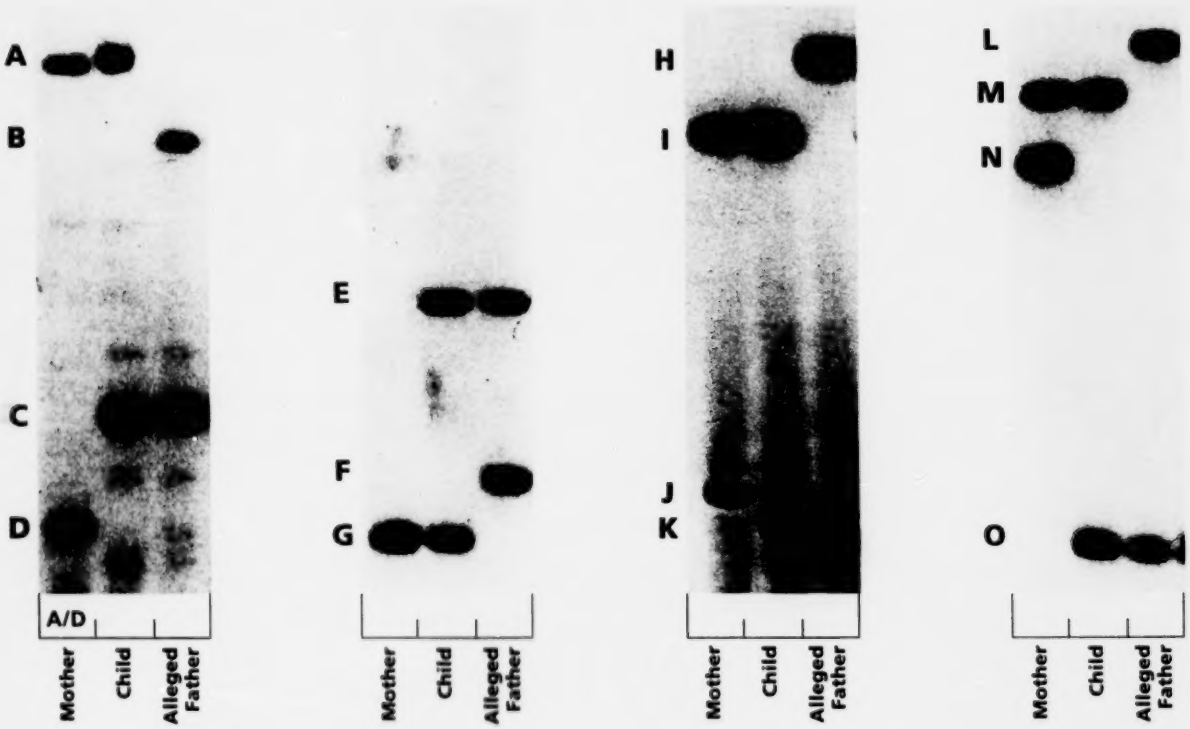
DNA "Fingerprinting" Worksheet



In this hypothetical paternity case, four autoradiographs show DNA "fingerprints" taken from three individuals: a mother, her child, and the child's alleged father. Each autoradiograph compares equivalent DNA segments from the three individuals. The two dark bands in each column represent one individual's DNA segments—one inherited from that individual's biological mother and the other from the biological father. These segments differ in length from person to person; for this reason they are used as genetic markers. Here, each length is designated by a letter, A through O. The two letters associated with each segment indicate the individual's genotype.

Instructions

1. Under each column in the autoradiographs, write the letters associated with each individual's genotype. For example, the genotype of the mother in the first autoradiograph is A/D. Then, circle the letter in the child's genotype that represents the gene inherited from the mother.

2. Which "letters" must the child have inherited from its father?

3. Based on this information, what evidence suggests that the alleged father could be biologically related to the child?

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Activity Expectations and Outcomes

All measurements in this guide are in metric units.

km	miles
g	ounces
m	feet
ml	fluid ounces

Disease Detectives

If you have a large group (35 or more) you may want to begin with two test tubes containing NaOH. The final number of "infected" test tubes will vary depending on (1) the number of trades and (2) how many trades occur between already infected tubes.

A possible method to find "patient zero" is to have each student write his or her name on the board and underneath it the names of students with whom he or she exchanged fluids in the order in which the exchanges occurred. Then, as a class, highlight the names of the currently "infected" people (shown in bold in sample below).

This visual representation can help clarify which students may have infected one another, and in what order. Students who "test positive" and find that everyone with whom they traded also tested positive may be original carriers of the disease (Cal, Dee, Gib and Hal in this example). It is likely that there will be several candidates for "patient zero." Cross-checking the history of each contact can narrow the field, but probably not to less than two candidates. (For example, here, Cal and Dee can be eliminated as "patient zero" because their first contacts, Bob and Ed, did not infect their own second contacts, Fran and Ilsa; either Gib or Hal, however, could be "patient zero.") If students are unable to reach a clear conclusion, the exercise will raise useful questions about the challenges facing real epidemiologists as they try to trace the sources of an infection.

Sample Chart Tracing Infection

Exchange 1		Cal	Bob	Ed	Dee	Ann	Hal	Gib
Exchange 2			Gib	Hal		Bob	Cal	Dee
Exchange 3	Gib	Dee	Ed	Bob	Cal		Ann	Lin

Universal Proportions

Students' first models may vary greatly. Students can test the 50:1 ratio of the volumes of Earth to Moon by comparing the diameters of their models to the actual planetary diameters. Earth's diameter = 12,756 km. The Moon's diameter = 3,476 km. Have students use these numbers to find that the Moon's diameter is about 1/4 of Earth's. They can then check to see that the diameters of their models show the same relationship.

Students' estimations of distance between Earth and the Moon again may vary widely. They can find the actual scale distance by first determining the scale of their models based on the ratio of their model Earth's diameter and planet Earth's actual diameter. For example, if a model of Earth measures 8.5 cm in diameter, then 1 cm represents 1,500 km and the distance between the Earth and Moon models should be approximately 2.6 m. At this scale, the space shuttle's orbit would be about 0.41 cm above model Earth's surface, and the Sun would be about 1,000 m away.

If students have trouble with the solar system map, suggest that they place the Sun at one end of the paper and Pluto at the other end. Then they can determine the scale based on the distance between them. A scale of about 1 cm = 50 million km works well, putting Pluto approximately 118 cm away from the Sun. The map's scale will not be detailed enough to show the distance of the Moon from Earth. For that, students would need to use a scale of about 1 cm = 1 million km. Then, a map showing both the Moon and Pluto would be about 59 m long.

To calculate positions of Alpha Centauri, the center of the Milky Way, and M31 on the solar system map, students need to determine the length of one light-year (in the scale they are using). For example, at a scale of 1 cm = 50 million km, one light-year (9,450,000,000,000 km) = 189,000 cm or 1.89 km. On that map, the distance from the solar system to Alpha Centauri would be about 8.13 km, from the Sun to the center of the Milky Way would be 56,700 km (about 4.5 times the distance around the earth), and from our galaxy to M31 would be 3.78 million km.

Testing, Testing

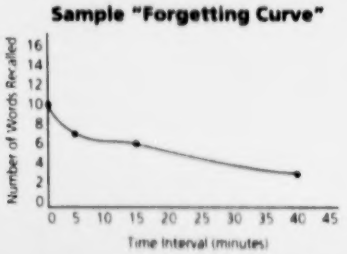
1 they catch mice
2 they are cheaper
3 it wears well
4 what a man does...
5 I don't know him...
9 an automobile is more...
10 make a wide, light surface
11 it avoids confusion...
12 it gives them control...
13 water expands...
picture 12 pig's tail
picture 13 crab's small left claw
picture 14 cat's shadow
picture 15 man's bowling ball
picture 16 net

Memory Lane

We are able to hold facts in short-term memory as long as we actively think about them. Once we stop, short-term memory fades after about 20 seconds. Short-term memory also has a finite capacity; it retains 7 items, plus or minus 2. Short-term memory is more accurately called "working" memory, suggesting a work space in which we actively organize and manipulate information, rather than a passive storage place.

Recall is one measure of memory. Students' graphs should show a decrease in short-term memory over time, usually represented by a classic, negatively accelerated curve. A week or two after the activity, ask the class to recall as many items as they can. Students may be surprised at what they remember—that is, how flat the forgetting curve becomes after the initial steep decline.

Sample "Forgetting Curve"



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Students may propose a number of valid hypotheses about the nature of memory. They may find that they are more likely to recall meaningful information—names rather than other words, and words rather than nonsense syllables. They may also hypothesize that repetition aids memory: Repeated nonsense syllables are more likely to be recalled than those heard only once. In addition, items that stand out, such as the shouted syllable, are typically remembered more often than other nonsense syllables. Finally, students may observe that it is easiest to remember items near the beginning of the list; items near the end of the list are remembered more often than items just past the middle of the list.

Super Polymers!

For best results with this activity, students should understand polymer structure, osmosis/diffusion, and hypertonic, hypotonic, and isotonic environments.

Superabsorbents are made of a polymer network and can absorb large amounts of water due to their ionic nature and interconnected structure. This network creates a membrane that allows water diffusion. The polymer absorbs water by osmosis: The large concentration of sodium inside the polymer network makes water flow into the polymer until equilibrium is reached, or the concentration of ions in the polymer equals the concentration of ions outside the polymer. (From a biological point of view, the polymer is hypertonic relative to the outside environment, which is hypotonic. Therefore, water diffuses into the polymer until equilibrium is reached.) Water is caught and held inside the polymer network by hydrogen bonds that it forms with the sodium acrylate monomers, forming a gel.

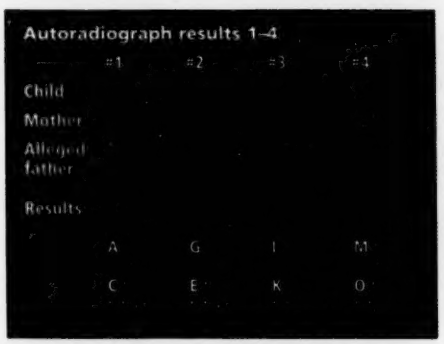
Sodium polyacrylate can absorb about 800 times its weight in distilled water (800 g water:1 g polymer) and 300 times its weight in tap water. Absorbency decreases as the water's ion concentration increases. In diapers, the polymer's absorbency is only 30 times its weight due to urine's salt concentration (0.9% NaCl [aq]) plus the mechanical pressure from a baby's weight.

Students' results may differ from these absorbencies. Students should hypothesize why their results differ based on the method they used. For the suggested method, the amount of time allotted for absorption, variations in initial weights of dry polymer, and human error in determining when saturation is reached can lead to slightly different absorbency ratios. To vary this activity, students might keep the amount of water constant and determine the amount of polymer needed to absorb it. Or, they might vary salt concentration and determine the amount of polymer that can be gelled.

DNA "Fingerprinting"

An autoradiograph is a photographic image that lets us visualize segments of DNA. A process called gel electrophoresis separates DNA fragments by length. Each piece of DNA is labeled with a radioactive marker and recorded on x-ray film. The resulting series of bands show the different fragment sizes and can be used to compare DNA from different individuals.

The autoradiographs show that the letters in the child's genotype match those of its mother and the alleged father; therefore the alleged father is most likely biologically related to the child.



According to the University of Utah, this genetic test based on four markers indicates that there is more than a 99 percent probability that the alleged father is the child's biological parent. Because statistical calculations prevent a 100 percent probability of paternity, most courts accept a probability of 99.5 percent or greater as evidence of paternity. An "exclusion" result, where the patterns do not match between a child and the alleged father, is unequivocal evidence of non-paternity. Remind students that genetic tests can only absolutely disprove, not prove, relationship.

The Dating Game

Each of the isotopes in the activity—represented by pennies, dice, or sugar cubes—has a different half-life based on rate of decay. The rate of decay for each is determined by the likelihood that one unit of the isotope will be removed after a trial. The probability that a penny lies heads up is 1:2; that a sugar cube shows a dot is 1:6; and that a die shows a 1 or 2 is 1:3. Based on these probabilities, students will remove about half the pennies, about one-sixth of the sugar cubes, and about one-third of the dice after each trial. Thus a half-life for pennies will be about 1 trial; for sugar cubes, 3.8 trials; and for dice, 1.7 trials. The slopes of the graphs should show the number of radioactive, or undecayed, atoms declining exponentially and gradually approaching zero.

Just as it cannot be predicted exactly when an individual sugar cube will show a dot side, it cannot be predicted exactly when an unstable nucleus will decay. However, if a large enough number of sugar cubes are tossed, the probability of a dot side up occurs at a predictable rate. Similarly, a large group of identical nuclei will decay at a predictable rate. Scientists can use this predictable decay rate to estimate the age of materials that contain radioactive substances. One way is by comparing the ratio of radioactive atoms to stable daughter atoms. The greater the percentage of daughter atoms, the older the specimen. A formula based on the rate of decay helps pinpoint the actual age.

Procedure 2 helps assess students' understanding of half-life. If students have difficulty, suggest that they choose an age for their rock that is a multiple of the half-life. For example, suppose a rock has a half-life of 3 trials and 1 trial equals 1,000 years. Its half-life (or the time it takes for half of its atoms to decay) would be 3,000 years. If this rock were 6,000 years old, it would have gone through two half-lives. Therefore, given 80 original atoms, 40 would have decayed after the first half-life and the other 40 would not have decayed. Over the second half-life, half of the remaining 40 radioactive atoms would decay, leaving 20 undecayed atoms and 60 daughter atoms. A box representing this 6,000-year-old rock would have 20 of the original atoms and 60 daughter atoms.

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Resources

Medicine and Health

Garrett, Laurie. *The Coming Plague: Newly Emerging Diseases in a World Out of Balance.* New York: Penguin Books, 1994. A journalistic account of emerging infectious threats, and the social and economic factors that foster them.

Outbreak Home Page
http://www.outbreak.org. Great information source on emerging diseases.

The Wright Stuff Home Page
See Poliomyelitis: The Era of Fear, at http://www.tufts.edu/as/wright_center/wstuffr.html. Activities, discussion questions, and a letter from FDR's doctor after FDR was stricken with polio.

For health and population statistics:
World Health Organization Home Page: http://www.who.org—links to reports on disease outbreaks, and global population and life expectancy statistics; U.S. Census Bureau Home Page: http://www.census.gov—access to world population statistics, historical info, and demographic and socioeconomic data by country; and Zero Population Growth Home Page: http://www.zpg.org—info on population growth and teaching materials.

WGBH Videos* NOVA "The Universe Within"—how our bodies fight infection, digest food, and survive; "Cut to the Heart"—controversial new methods in heart surgery; "MD: The Making of a Doctor"—share the days of seven medical students.

Physics and Astronomy

Dubeck, Leroy W., Suzanne E. Moshier, and Judith E. Boss. *Science in Cinema: Teaching Science Fact through Science Fiction Films.* New York: Teachers College Press, 1988. Provides teaching suggestions for using selected science fiction films in the classroom. Stresses factual accuracy and social issues.

Hubble Space Telescope Home Page
http://www.stsci.edu. The Space Telescope Science Institute presents news and information about the Hubble, a gallery of photographs, and educational resources and activities.

Leverington, David. *A History of Astronomy, From 1890 to the Present.* New York: Springer-Verlag, 1995. Summarizes technologies and discoveries of the past century, and covers scientists, both famous and obscure.

Mt. Wilson Observatory Home Page
http://www.mtwilson.edu. Offers a virtual tour of the observatory, descriptions of the telescopes in use there, historical information, and a Telescopes in Education project.

WGBH Videos* NOVA "Einstein Revealed"—how one man's ideas changed our world; "Death of a Star"—witness a supernova in action; "Hunt for Alien Worlds"—recent discoveries beyond the solar system.

Human Behavior

Cohen, Daniel. *Intelligence: What Is It?* New York: M. Evans and Co., 1974. Aimed at high-school students, with chapters discussing the history of intelligence testing and the ongoing controversy over race, heredity, and IQ.

Gallant, Roy A. *Memory: How It Works and How to Improve It.* New York: Four Winds Press, 1980. Aimed at high-school students, this book discusses what scientists know about memory and tips and tricks for improving it. Chapter 4 describes split-brain experiments and how the dual structure of the brain relates to memory.

Still Killing Us Softly: Advertising Images of Women and *Advertising Alcohol: Calling the Shots,* two videos based on lectures by Jean Kilbourne. From Cambridge Documentary Films, Inc., P.O. 385, Cambridge, MA 02139. (617) 484-3993. Fast-paced, funny, thought-provoking presentations on how advertising conveys messages about individuals, behavior, and society.

Technology

Carey, John. *Eyewitness to History.* New York: Avon Books, 1987. Contains first-hand reports of major world events, including the first moon landing and a visit to Hiroshima in September 1945.

Toshiba/NSTA ExploraVision Awards Program Toshiba Corporation and the National Science Corporation jointly sponsor an annual competition for students (K–12), challenging them to envision a technology 20 years from now. For information, call (703) 243-7100 or on the Web at http://www.nsta.org/programs/explora.htm.

Williams, Trevor I. *Science: A History of Discovery in the Twentieth Century.* New York: Oxford University Press, 1990. An excellent overview of twentieth-century science and technology with a wealth of full-color pictures.

WGBH Videos* NOVA "The Race to Catch a Buckyball"—the chance discovery of a new carbon molecule. *The American Experience* "The Wright Stuff," "The Boy Who Dreamed of Television."

Earth and Life Sciences

Lewin, Roger. *Bones of Contention: Controversies in the Search for Human Origins.* New York: Simon and Schuster, 1987. A journalistic account of controversial discoveries and intellectual debates in paleoanthropology. Chapters 2 and 3 focus on scientists' reactions to the discovery of the Taung skull and discuss the Piltdown fraud.

Milner, Richard. *The Encyclopedia of Evolution: Humanity's Search for Its Origins.* New York: Facts on File, 1990. A readable, thorough, and well-illustrated reference covering earth science and the life sciences.

U.S. Geological Survey Home Page
http://www.usgs.gov. Up-to-the-minute data on earthquakes and other phenomena, history of plate tectonic theory, etc. Features activities, resources, and web links for teachers.

WGBH Videos* NOVA "The Story of Lucy"— discover the link between humans and apes; "The Creative Revolution"—trace the evolution of the human race; "Cracking the Ice Age"—did the Himalayas cause the Ice Age? *The American Experience* "The Great San Francisco Earthquake."

*NOVA and *The American Experience* videos are available from WGBH Boston Video, P.O. Box 2284-9050, South Burlington, VT 05407-2284. To order, call 1-800-255-9424.

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Major funding for *A Science Odyssey* is provided by the National Science Foundation.

Corporate sponsorship is provided by IBM. IBM is a registered trademark of IBM Corporation.

Additional funding comes from public television viewers, the Corporation for Public Broadcasting, The Arthur Vining Davis Foundations, Carnegie Corporation of New York, and Becton Dickinson and Company.

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